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August 11–13, 2003

NASA Headquarters
Washington, D.C.

MEETING REPORT

Marc S. Allen	**Andrew B. Christensen**
Executive Secretary	**Chair**

SPACE SCIENCE ADVISORY COMMITTEE (SScAC)
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TABLE OF CONTENTS

Meeting Report Prepared By:
Robert J. Katt, Consultant
RS Information Systems, Inc.

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Chair's Remarks and Agenda Review
Dr. Andrew Christensen, Chair of the SScAC, opened the meeting at 8:30 a.m. and welcomed the new and returning members. Dr. Marc Allen, the SScAC Executive Secretary reviewed the requirements for a meeting of an advisory committee in accordance with the Federal Advisory Committee Act (FACA).

Office of Space Science Status and Question Period
Dr. Edward Weiler, NASA Associate Administrator for Space Science, provided an update on program and mission status in the Office of Space Science (OSS). Both of the Mars Exploration Rovers (MERs) are en route to Mars after successful launches in June and July. There were many problems with the Delta launch vehicle. Some residual issues remain with the Mossbauer spectrometer on both spacecraft. Dr. Weiler reviewed other launches completed or planned for 2003, including the scheduled launch of the Space Infrared Telescope Facility (SIRTF) on August 23 and Gravity Probe-B (GP-B) on November 13. The Swift Gamma-ray Burst Explorer is on schedule for launch in January 2004.

The launch of the Mercury Surface, Space Environment, Geochemistry and Ranging (MESSENGER) mission, scheduled for March 2004, is in jeopardy. The mission is also exceeding its cost cap. The Applied Physics Laboratory, the project contractor, has requested an additional $12 million, and the total estimated mission cost under the replan will be at least $309 million to $316 million. Dr. Weiler emphasized the negative consequences for both the MESSENGER project and the entire Discovery program if the cost cap is relaxed instead of terminating the project. He said he would not break the cap unless the SScAC advises him that the science is worth the investment and the Principal Investigator (PI) and mission management organization appear likely to meet their commitments under this replan. He asked the SScAC for its recommendations on how NASA should respond to the cost growth issue. He noted that discussion of MESSENGER was included in the committee's afternoon agenda.

Calendar year 2004 will be a busy time for the Mars Exploration Program, with continuing operations by missions already at Mars and new landings and orbital insertions. Other planetary exploration events will include the end of the Galileo mission this September, orbital insertion of Cassini/Huygens in July 2004, and a sample return to Earth from Genesis in September 2004. Stardust will fly through the tail of comet Wild 2 in January 2004, with a sample return in 2006.

Additional funding for the James Webb Space Telescope (JWST) replan will come from the Hubble Space Telescope (HST) funding. Dr. Weiler noted that the HST was originally sold to Congress and the administration as a 15-year mission. All mission requirements for the HST will be completed in 2005. Although the mission has been extended to 2010, important assumptions made in the rationale for that extension are now in question because of Shuttle safety issues. The HST will be brought down from orbit by a robotic system. Full-cost accounting means that the cost of a Shuttle mission to the HST is borne entirely by OSS. In addition, the delays in the planned fourth Shuttle servicing mission to the HST incur costs. Waiting for a Shuttle servicing mission to the HST costs $10 million a month. With respect to the JWST, as well as HST servicing and mission extension, Dr. Weiler reviewed what NASA has promised the science

community. Even if the HST fails before 2010, NASA has promised full funding of the guest investigator program for research on HST archival data. Archival research led to two major scientific discoveries in the past year: one on dark energy, the other being the identification of the oldest known extrasolar planet. The HST guest observer budget of $30–40 million per year is more than the total National Science Foundation (NSF) budget for astronomy grants. Whether a Shuttle mission to service the HST will even be allowed after Return to Flight is in question. The earliest date for a servicing mission is late 2005, with 2006 more likely. A blue ribbon HST Transition Review Panel, chaired by John Bahcall, met last month. Its final report is expected in mid-August. NASA is also waiting for the final report from the Columbia Accident Investigation Board (CAIB), which will significantly affect the future of the Shuttle program.

Based on media coverage of OSS missions and other metrics, the OSS Education and Public Outreach (E/PO) program is doing well. The House science committee markup of the FY 2004 budget for NASA includes 73 earmarks totaling over $130 million. Half of the money for the New Frontiers Pluto mission has been cut by the House committee. This cut will delay launch by one year, and the delay will mean that the trajectory assist from Jupiter will be lost. The time to reach Pluto will increase by 3 to 4 years. Funding for the JWST has been cut by $20 million; funding for the Space Interferometry Mission (SIM) has been cut by $8 million. Dr. Weiler believes a continuing resolution will be needed again this year, which will affect scheduling and delay new starts included in the budget.

Dr. Weiler summarized the OSS responses to recommendations from the SScAC after its March 2003 meeting; details on the responses are included in the briefings to the committee by other OSS managers. **[Action Item]** With respect to the SScAC request for a detailed briefing on the research and analysis (R&A) budget, Dr. Weiler said that the members should receive a copy of the recently completed cross-enterprise analysis of R&A. **[Action Item]** A detailed briefing on R&A will be on the agenda for the November meeting.

During the discussion period, Dr. Weiler addressed a question on the language in the conference committee bill for the FY 2003 budget about using funds from the JWST budget to maintain the HST. Other topics discussed were the cost of bringing the HST down via a robotic mission, the effects of full-cost accounting on the budgets for Project Prometheus, the Jupiter Icy Moons Orbiter (JIMO) mission, and OSS project management generally. The requirement for full-cost accounting of civil servants primarily affects OSS programs at Goddard Space Flight Center (GSFC). Members expressed differences of opinion from Dr. Weiler's interpretation of what the latest *Decadal Survey* by the National Research Council (NRC) implies about the HST. The SScAC members and Dr. Weiler discussed MESSENGER issues about which Dr. Weiler had requested the SScAC's recommendations. These topics included the history of explicit cost caps on PI-led missions, past experience with terminating projects that ran into serious cost problems, the balance between selection on the basis of scientific merit and cost realism, providing adequate project management experience to support first-time mission PIs, and increasing the visibility to the scientific review panel of the Technical, Management, Cost, and Other Factors (TMCO) review of proposals. Options for servicing the HST were also discussed.

Dr. Weiler replied to a question about Code S E/PO and the new Code N by saying that the mainstream Code S E/PO program is continuing within the new Agency-wide E/PO framework. Small mission launch capability was discussed, with more details to come from the Sun-Earth Connection (SEC) Division briefing. In response to another question, Dr. Weiler said he did not expect the costs of Shuttle Return to Flight within Code M to affect Code S budgets, but there could be further delays, which would incur costs for Code S missions. Space science as a principal driver for continuing the human exploration of space was discussed, particularly as a

long-term driver beyond the immediate issues of ISS completion and Shuttle Return to Flight. Dr. Weiler expressed the view that robotic missions can be used for planetary exploration in the near term, but in the longer term humans can do some aspects of exploration better than robots. Dr. Christensen added that the NASA Advisory Council (NAC) is also considering the role of humans in space; the SScAC could provide input to those considerations. Dr. Allen responded briefly to members' concerns about mechanisms for the subcommittees of the SScAC to maintain their relevance if they are not formal advisory committees under FACA. (This issue was also addressed in later committee discussions.) A question of the mission reserve requirement and its impact on the appropriate cap for categories of missions was raised but held for later discussion.

Sun-Earth Connection Division Report

Dr. Richard Fisher, the Division Director, reported on the current strategy, status, and tactics for the SEC Division. Flight programs in the division are decreasing, but an increasing budget will help to expand SEC activities. Dr. Fisher reviewed the NASA goals relevant to the SEC Division and the relation of the division's three science objectives to its two major programs: Solar-Terrestrial Probes (STP) and Living With a Star (LWS). Data sets constructed from observational data from multiple spacecraft are being proposed more often in research proposals and are used more often in projects. To meet the increased work load from the operating missions, Dr. Fisher is recruiting new personnel; several offers for program scientist and program executive positions have been accepted.

In the LWS program, initial confirmation review for the Solar Dynamics Observatory (SDO) is scheduled for this fall. The Phase A studies for the three SDO instruments are being evaluated. A Geospace Announcement of Opportunity (AO) will be issued in fall 2003. The division is working with the National Oceanic and Atmospheric Administration (NOAA) to place a far-UV instrument on a geosynchronous satellite as a mission of opportunity. The Targeted Research and Technology Definition Team has delivered its final report on the kinds of models that will be needed to fill in the relatively sparse distribution of observed data with output from models. A mission operations working group (MOWG) for LWS has held its first meeting, which produced useful suggestions on partnerships for Geospace missions. A Sun-Climate Working Group is looking at areas for investment in sun-climate connections, such as solar influence on the upper atmosphere and on major terrestrial storms.

Within the STP program, the Thermosphere * Ionosphere * Mesosphere * Energetics and Dynamics (TIMED) spacecraft is operational and meeting its mission success criteria. The Japanese have announced a one-year slip in the launch schedule for Solar B. The cost implications will have to be accommodated within the program, by either using program reserves or adjusting the program to cover costs. For the Solar Terrestrial Relations Observatory (STEREO) mission, which is still in development, the independent review team has raised concerns about: (1) the rate of progress on mission instruments and spacecraft, (2) the workload at the Applied Physics Laboratory, (3) a cost overrun on a remote sensing instrument, the Sun Earth Connection Coronal and Heliospheric Investigation (SECCHI), and (4) a technical issue on the boom for the In situ Measurements of Particles and Coronal Mass Ejection (CME) Transients (IMPACT) instrument. Dr. Fisher described the actions taken or in progress with respect to each issue. STEREO is at risk of not meeting its launch schedule, and GSFC management is developing a recovery plan. Payload selection for the next STP mission, Magnetospheric Multiscale (MMS), is in progress.

Dr. Fisher next reviewed the SEC missions under the Explorer Program. The Ramaty High Energy Solar Spectroscopic Imager (RHESSI) spacecraft is operational and meeting mission success criteria. The Aeronomy of Ice in the Mesosphere mission (AIM) was recently selected as

a Small Explorer (SMEX) mission. Time History of Events and Macroscale Interactions during Substorms (THEMIS), an investigation of magnetic substorms, has been selected as a Medium Explorer (MIDEX) mission. The Coupled Ion-Neutral Dynamics Investigation (CINDI), a collaborative project with the Air Force Communication/Navigation Outage Forecast System, has been delivered and is ready for flight. The door for the Two Wide-angle Imaging Neutral-atom Spectrometers (TWINS) spacecraft A has been successfully qualified, and the NASA part of the work is proceeding well.

For the New Millennium Program technology program, the SEC Division has five missions in development (ST-5 through ST-9). Dr. Fisher reviewed the status of each. The ST-5 mission had been formulated on the assumption that costs for small expendable launch vehicles would decrease. If the Evolved Expendable Launch Vehicle (EELV) secondary payload solution does not succeed, ST-5 will be pushing against its cost cap and may have to be terminated. For ST-8, there are issues in launching with a Pegasus vehicle.

Heeding the advice of the Sounding Rocket Program Committee, the SEC Division is working on longer flights and controlled placement (trajectory) in rocket flights. Dr. Fisher discussed the technology plan for improvements, including improved rocket motor capabilities being considered. The flight rate is holding at 30 flights per year. Payload proposals over the past year seem to suggest declining activity in the science community that uses these flights. If contingency funds from FY03 are available, Dr. Fisher may use them for the sounding rocket technology upgrade program.

As another perspective on SEC Division Operating Missions, Dr. Fisher compared the observing capabilities in 1994 and 2004 for each stage in the Solar-terrestrial particle chain (from imaging the solar source to atmospheric and ionospheric coupling). The division recently completed a senior review of observing assets whose missions will be extended. Thirteen missions were confirmed for extended mission operations. The EXODIS proposal to reuse hardware on the Genesis proposal was of great interest but was not accepted because of cost. The review team identified areas for savings and future ramp-downs in the 2006-2007 time frame. Dr. Fisher is hoping to augment the guest investigator program with some of the savings identified. Among his summary list of issues and concerns were (1) identifying resources to accomplish the senior review's technology upgrade plan, (2) meeting the cost and programmatic challenges to flight program budgets, (3) identifying resources and support for a Solar Probe mission as part of the LWS program, and (4) optimizing the existing missions to achieve SEC strategic science goals. Dr. Fisher concluded with his plans for near-term priority activities, such as recovering the schedule for STEREO, issuing the LWS Geospace-1 AO, and formulating the fourth STP mission (MMS).

Solar System Exploration Division Report

Dr. Colleen Hartman, Division Director, began her status update on the Solar System Exploration Division (SSED) with the New Frontiers Program, which is competitive and will be structured like the Discovery program. The AO for the second New Frontiers mission will include all four of the *Decadal Survey* priorities (the first mission is New Horizons/Pluto-Kuiper Belt). This AO is for the science, not the implementation plan, and will be released before the FY 2004 budget is resolved, probably in August 2003. A 25 percent unencumbered reserve will be required. The Discovery AO, which will have a cost cap of $350 million with a 25 percent unencumbered reserve, will be delayed until issues with MESSENGER and Deep Impact are settled. Dr. Hartman reviewed the R&A funding, including the direct R&A budget line and R&A embedded in new programs starting in FY 2003 (R&A embedded as data analysis or as mission-funded research) and FY 2004 (the Outer Planets Fundamental Research Program). She described the

difficulty in preserving freestanding budget lines for R&A when budget decisions are requiring metrics for the results to be achieved.

One benefit to SSED programs of Project Prometheus will be new radioisotope thermoelectric generators (RTGs) for missions to the outer planets. Dr. Hartman emphasized that JIMO is a science-driven mission using new nuclear power technologies to enable much more extensive science results. The current JIMO plan exceeds the *Decadal Survey* recommendation for a Europa orbiter as a high-priority flagship mission. The In-Space Propulsion (ISP) program has been progressing with Solar Sails and Aerocapture activities from the first NASA Research Announcement (NRA) and work on the Next Generation Ion Thruster. ISP is a mid-Technology Readiness Level (TRL) program, not early technology innovation. It is intended to fill the mid-TRL gap from TRL 4/5 to TRL 8.

In Dr. Hartman's assessment of project status, the New Horizons/PKB mission is now *red* because of launch vehicle cost and dependence on the Department of Energy's (DOE's) production of the RTGs. MESSENGER, which is *yellow*, will continue to be funded until the review process comes to a decision. The Dawn mission is *yellow* because of the need to build up reserves, currently at 14 percent, to move out of Phase B. The Dawn PI needs to implement descopes to instruments and targets to increase the reserves. The weld design for the inertial reference units (IRUs) for Deep Impact has been judged to be flawed, requiring mounting adjustments and additional testing before the existing units can be flown. In parallel with corrective work by the IRU supplier (Northrop Grumman), alternate hardware sources are being investigated. The Stardust spacecraft continues in cruise mode after completing collection of interstellar dust. Solar wind sample collection by Genesis is continuing. The battery temperature problem on Genesis appears stable as the spacecraft passes through aphelion, but a reaction plan for excess temperatures is in place. An independent group will consider cost recovery issues for the Deep Space Network cost overruns. Data requirements on the Planetary Data System are increasing as new Mars missions begin operations. Dr. Hartman ended by presenting scientific staff positions open in the SSED.

Project Prometheus/Nuclear Systems

Mr. Alan Newhouse, Director of the Project Prometheus program, provided an update on the program. (Dr. Christensen recused himself from the discussion of Project Prometheus because of potential conflict of interest. Dr. David McComas chaired the SScAC in his stead.) Mr. Newhouse reviewed the history of Project Prometheus and the ways the program will provide improved power capability for solar system exploration. The four key program components are two modes of energy generation (radioisotope decay and fission reactor); technologies for converting heat to electricity; and electricity utilization for propulsion, powering instruments, and communications. Mr. Newhouse reviewed the mission types for which nuclear fission reactors would be justified and the energy, power, and science return advantages of a fission energy source relative to solar or chemical energy sources.

There are five components in the program for new radioisotope power sources (RPSs). The component for Advanced Systems Development will develop smaller RPS units, ranging in power output from milliwatts to 1 watt. DOE is considering resuming production of plutonium-238, which will be needed for expansion of RPS utilization. Other components of the RPS program will develop a Multi-Mission RTG and an RTG based on the Stirling cycle, which is already used in cryocoolers. Ten projects in advanced RPS research and technology were selected in June 2003 via a competitive NRA.

For the components of Project Prometheus dealing with fission power (fission reactor source, power conversion, and electricity utilization), three kinds of power conversion are being considered. Mr. Newhouse reviewed the reactor research topics and technology issues in each. He also described the research in progress on electric propulsion. Organizational principles used by the program include involvement of DOE and the NASA centers in managing the scientific research selected through competitive NRAs. In response to the SScAC's recommendation for attention to the Project Prometheus management plan, Mr. Newhouse said that management plans are being developed, the program agrees that management will be difficult, and the DOE Office of Naval Reactors is being brought in to participate. He also reviewed the elements of experience and procedure that will support designing for safety. He concluded with the program's theme statement that Project Prometheus will enable a new paradigm in the scientific exploration of the Solar System.

Mars Exploration Program Report

Mr. Orlando Figueroa, Director of the Mars Exploration Program, presented the program's status and recent progress to the SScAC. He began with the three objectives of the program and related them to activities in the present decade and planning for the next decade. A third mission extension for Mars Global Surveyor is in review, and an extension for Odyssey is being planned. The MERs and the Mars Reconnaissance Orbiter (MRO) are fully funded. There are some issues with MRO instruments. The Scout mission for 2007 is fully budgeted, and phase A of the Mars Science Laboratory (MSL) will begin this fall. Mr. Figueroa has some concern about planetary protection requirements for MSL because of possibilities for forward contamination. He described progress on the Mars Telecom Orbiter (MTO), for which phase A is expected to start in spring 2004. R&A for the Mars program has been funded in accordance with administration guidance. Mr. Figueroa discussed issues with continuing funding of the base technology program beyond FY 2005. (Base technology benefits the program at large, rather than just being a requirement for a particular mission.) He reviewed other major cost issues that could impact the program. In preparation for the next decade of Mars exploration, the program has developed four options (pathways) for science and investigations. Mr. Figueroa emphasized the importance of starting a budget wedge for next-decade missions in FY 2005.

International collaboration has become a major issue for the program. In Mr. Figueroa's view, foreign collaboration essentially collapsed over the past year as other nations experienced budget problems. NASA is working on rebuilding it. The Canadian Space Agency (CSA) is a major partner in the newly selected Phoenix Scout mission. Phoenix is a lander that will go to the ice-rich high northern latitudes to investigate chemistry, organics, and climate. It is the first PI-led, fully competed mission to Mars. There are also opportunities to collaborate with Russia. Mr. Figueroa reviewed highlights of results from international missions to Mars and selection of international investigators for projects.

Science highlights in the program include selection of new investigators to participate in Mars Express, U.S. involvement in all Mars orbital missions and the Beagle-2 lander, selection of new PIs under the Mars fundamental research program, a new round of proposals in review for the Mars Data Analysis Program, the Special Products Initiative for data products across the Mars program, and a round of new proposals under review for the Mars Instrument Development Program.

With respect to the status of the two MER spacecraft (Spirit and Opportunity), launch vehicle and weather problems delayed the launches. The Mossbauer spectrometer on Spirit gave some anomalous readings after the launch; the source of the anomaly is under review. On Opportunity, the internal calibration source for the spectrometer is the issue, but external sources can be used

to calibrate the instrument. A tiger team is investigating the problems and developing recovery modes to sustain the science objectives of the missions. There will be an opportunity to retarget the MERs to other landing sites in September.

Dr. Christensen congratulated Mr. Figueroa and the teams involved on the MERs for their successes over the past year in preparing for launch on an extremely tight schedule.

During lunch, the SScAC received an informal briefing from Dr. Mauro Giavalisco of the Space Telescope Science Institute on the Great Observatories Origins Deep Survey (GOODS) and preliminary results from the Advanced Camera for Surveys (ACS) on the HST.

Introduction to Cost Issues for Community Mission Lines

Dr. Weiler opened the afternoon session by reviewing the issues related to the cost growth on the MESSENGER project. The Applied Physics Laboratory has requested $12 million over the guideline to complete phases C and D. Dr. Weiler is willing to allow the mission to break its cost cap, but only if the science community agrees on the mission's importance and accepts the consequences as worth the cost. The community, via the SScAC, also needs to suggest how to increase incentives for PI-led missions to stay within the agreed cost caps. Dr. Weiler discussed the status of other PI-led missions that are approaching their cost caps.

MESSENGER Science and Project Status

Dr. Sean Solomon, PI for MESSENGER, gave a presentation on the MESSENGER mission, including the scientific rationale for a Mercury orbiter, description of the mission, and the development and budget status of the project. The scientific rationale began with the properties of Mercury that make it significant for planetary science. The last mission to Mercury was Mariner 10, which made several flybys in 1974-1975. Dr. Solomon summarized what was learned from those brief visits. He then summarized the history of MESSENGER's selection as a Discovery mission and the original time line for development phases, launch, and operations. MESSENGER is designed to provide observations relevant to six key science questions about Mercury. Dr Solomon reviewed the science background for each question, leading up to the ways MESSENGER would contribute to answering them. For example, MESSENGER's capability for remote chemical sensing of the surface of Mercury will provide chemical composition data that can distinguish among competing hypotheses about how Mercury formed. Among the science questions MESSENGER can address are unresolved issues about Mercury's geological history, magnetic field, and magnetosphere. Questions about the planetary core and composition of the exosphere can be addressed. Dr. Solomon noted that the measurement objectives, which have remained the same since the mission was proposed, derive from the key science questions and the science context for addressing them. MESSENGER will have a payload of seven instruments plus radio science.

Dr. Solomon next discussed the baseline and backup launch opportunities for MESSENGER. The baseline trajectory, consistent with launch in March 2004, will use two Venus flybys and two Mercury flybys to achieve orbital insertion on the third approach to Mercury, in April 2009. The flybys will be used for useful science observations of Venus and Mercury. The backup trajectory, consistent with a launch in May 2004, has three Venus flybys rather than two and would arrive at Mercury three months later than the baseline. The elliptical orbit around Mercury will have periapsis at 200 km, apoapsis at 15,193 km.

Dr. Solomon described six factors that had contributed to MESSENGER's cost growth, including complexities introduced by efforts to reduce mass, development challenges resulting from early design decisions, delays in transferring veteran staff from other projects, fabrication bottlenecks

due to subsystem design delays, problems with vendors, and changes in risk tolerance programmatic requirements following losses and anomalies in other NASA missions. Delays that led to increased staff time have been a major factor in the cost overrun. Reviewing the mission cost history, Dr. Solomon said the severe cost growth occurred in FY 2003. The project team's currently estimated total cost for the mission (assuming a March 2004 launch) would have been covered by a 20 percent reserve on the initial mission cost estimate. The original project budget assumed reserves of 13.6 percent. The project is still on track for a March launch, but the schedule is tight. A May 2004 launch would add $8.8 million to the cost.

In response to a SScAC question, Dr. Solomon said that the six factors he cited contributed more or less equally to cost growth. The risk reduction requirements after the loss of other NASA missions contributed less than the other five factors. (NASA provided additional funds to cover costs incurred because of the increased programmatic requirements.) Other topics discussed included the staffing plan and its assumption of a rapid ramp-up after confirmation, trajectory requirements if the flight were delayed to August 2004 (three Mercury flybys would be required prior to orbit insertion), and the tight schedule to meet a March 2004 launch date (e.g., inadequate time to respond effectively to major test milestones such as the thermal vacuum test). In response to a question about the PI's control over cost, relative to the mission contractor, Dr. Solomon said that his ability to respond to specifics in the budget from the mission contractor was limited.

MESSENGER and Discovery Programmatics

Dr. Colleen Hartman provided the programmatic context for the MESSENGER and Discovery Program issues before the SScAC. After her review of MESSENGER's budget history, Dr. Beichman suggested that a replan for an August 2004 launch might be better in the long run. Dr. Hartman then reviewed the budget history for Deep Impact, another Discovery mission. The general impact of cost growth on current Discovery missions is to delay the competition for, and selection of, future missions. For every $12 million added to current projects, the next Discovery AO is delayed by two months. In response to a question, Dr. Hartman said that delays due to MESSENGER cost growth will soon begin to affect the next AO schedule. She also addressed SScAC questions on whether the mission reserves count against the cost cap (they do), the extent to which other PI-led missions expend all their reserves, and the impact on MESSENGER of having major cost problems arise late in development. SScAC members also discussed indications of problems earlier in the process, although the cost consequences of those problems did not show directly in the budget until later. Dr. Hartman described changes in NASA oversight of Discovery missions to provide earlier warnings of problems. There will also be a retreat with Discovery managers to discuss lessons learned from MESSENGER and Deep Impact. In response to a question, Dr. Solomon said that the budget was on track until November 2003 (although reserves were being depleted). By the time of the January 2003 replan, the mission descopes would have produced minimal budget savings. Complementarities between MESSENGER and BepiColombo, the European Space Agency's (ESA) planned Cornerstone mission to Mercury, were discussed.

Committee Discussion

Dr. Jonathan Lunine, chair of the Solar System Exploration Subcommittee (SSES), discussed the SSES concerns and recommendations on MESSENGER and the Discovery Program, as stated in the SSES letter to Dr. Christensen (Appendix G). The SSES saw inadequate reserves as a generic problem for the Discovery program. Dr. Lunine said that the SSES quickly concluded that, because of the importance of its science, MESSENGER should not be canceled. The SSES recommended that, if MESSENGER continues, the planetary science community should accept a NASA requirement for a 25 percent reserve as a minimum on PI-led missions, with riskier missions requiring a higher level of reserves. For the next Discovery AO, the SSES recommended

increasing the reserve to 30 percent. There should also be more performance review and discipline exercised at earlier milestones, including stronger interaction between the science review and TMCO review during proposal selection for phase A.

The SScAC discussed the SSES findings and recommendations. Dr. David Spergel, chair of the Origins Subcommittee (OS), reported that the OS had also been briefed on MESSENGER and recommended that the mission continue. Dr. Christensen led a discussion of possible recommendations the SScAC might make to improve the processes in PI-led mission programs, including requirements or other statements in the AO, as well as changes in the proposal selection, mission development, and project review processes. The consensus among SScAC members was to support the SSES and OS recommendation not to cancel MESSENGER. There was also agreement that the basis was not well established for the requested additional funding for phase E of MESSENGER and that early signs of project problems had been overlooked or ignored by project management. SScAC members expressed a range of opinions on the required minimum reserve recommended by the SSES. PI control of contractors, contractor accountability for past overruns, and greater visibility of the TMCO review to the science review team were other issues discussed. Dr. Christensen closed the discussion, saying that the SScAC would return to these issues and topics later in the meeting.

Project Prometheus/JIMO Science

Dr. Jay Bergstralh, filling in for Dr. Hartman, described the science aspects of Project Prometheus and the JIMO mission. The Project Prometheus program is managed as a program office within OSS. The SSED holds responsibility for mission science, including the science for JIMO, which is the first mission within Project Prometheus. Project Prometheus responds to the three fundamental technology limitations on planetary missions, as identified by a SSES Technical Advisory Group: transportation, power, and communications. Beyond the asteroid belt, an energy source other than solar energy is needed. RPSs can meet the energy and power requirements for outer Solar System missions in the New Frontiers class. But nuclear electric power is needed for the large, flagship missions to the outer planets and their moons.

JIMO is a science mission that will use nuclear power technologies to enable a science return far beyond previous missions to the outer planets. The commitment to science in JIMO includes four new R&A programs for JIMO or post-JIMO missions in Project Prometheus. The JIMO instrument workshop will slip to January 2004. This workshop will provide the science community with information about capabilities that will be available for JIMO, to aid in preparation for an AO. A JIMO workshop in June 2003 had 114 attendees and provided the JIMO Science Definition Team (SDT) with community input on science objectives for JIMO. These objectives reflect the high mass, high data rate, high power, and ability to go in and out of orbit around Galilean satellites provided by propulsion and power technologies based on a fission reactor energy source.

Project Prometheus/JIMO Mission

Dr. Ray Taylor of the Project Prometheus program office, OSS, provided a programmatic and technology-oriented briefing on Project Prometheus and the JIMO mission. The project office is looking at the cost envelope for a suite of mission concepts to rationalize selection of a reactor design, rather than selecting solely on the basis of JIMO. This point led to discussion with SScAC members on how Project Prometheus envisions the suite of missions and defines the payload envelope. Members noted that the Vision Missions NRA was supposed to develop mission concepts recommended in the science road maps for the OSS themes. Dr. Taylor reviewed the history of the JIMO mission concept. After the *Decadal Survey* recommendation in July 2002 for a Europa mission as the priority flagship mission, NASA, with support from DOE, conducted

three studies of a Jupiter Icy Moons tour. Jet Propulsion Laboratories (JPL) began a feasibility study for JIMO in November 2002 and briefed the NASA Administrator in January 2003. A funding line for JIMO in the FY 2003 budget started planning earlier than anticipated. Three industry study teams are conducting trade studies on a spacecraft module and on space system integration and test. A JIMO SDT was chartered in March 2003 and in June collected community input on JIMO science objectives.

As currently envisioned, the JIMO spacecraft will enter orbit successively around each of three moons (Callisto, Ganymede, and Europa), then leave orbit to fly to the next destination. The fission reactor will be started up when the spacecraft is in stable Earth orbit but before it leaves Earth orbit. The Europa leg of the mission is short because of the high radiation environment at Europa. The project is compiling a list of existing radiation-hardened (rad-hard) parts and another list of what parts have to be developed in rad-hard forms. SScAC members discussed the rationale for orbiting Europa last and whether the mission should go to Europa directly. Dr. Taylor said that the SDT decided that Callisto and Ganymede would not be science limiting, and interactions with those planets, either by flybys or orbital capture, were necessary to spiral JIMO into Europa. [**Action Item**] Dr. McComas requested a report from the JIMO SDT to the SScAC.

In the current JIMO spacecraft concept, a 20-meter boom separates the instrument payload from the power conversion and reactor units. The industry teams are conducting trade studies on subsystem options such as the power conversion technology, reactor cooling technique, heat rejection alternative, and thruster technology. The total mass of this spacecraft concept is about 20,000 kg. It would be launched with a Delta IV Heavy or Atlas V rocket, as the new generation of EELV. For the engineering of the nuclear power subsystem, the project team is leveraging work by the DOE laboratories on heat-pipe cooled, lithium metal cooled, and gas cooled options for space-based reactor operations.

The industry studies for phase A are competition-sensitive. The government studies support the JIMO SDT and establish a technical baseline for cost estimates. They also develop the knowledge necessary to evaluate industry studies and accomplish source selection activities downstream. JPL will be the managing center for JIMO, and a project management structure is already being built up. In concluding, Dr. Taylor said that the Project Prometheus program office needs to pull together an integrated team for JIMO from across NASA. It must also draw on the expertise of the DOE labs and the DOE Office of Naval Reactors, as well as the results from the phase A industry trade studies. The JIMO science investigations will be openly competed, and the spacecraft contract will be competed. The launch vehicle will use the existing NASA process for expendable launch vehicles (ELVs). In response to a question, Dr. Taylor said that a "substantially" full-scale test of the non-nuclear subsystems (power conversion, heat rejection assembly, and a mockup of the instrument module) could be performed. The test item would have neither the reactor component nor the actual scientific instruments. The issue of reactor testing is still being investigated.

Committee Discussion

Dr. Christensen reviewed the issues before the committee, noting that the discussion of MESSENGER had been cut off and should be resumed. He summarized members' suggestions for incentives to avoid this outcome on other PI-led missions. The topic of required reserves was revisited, and Dr. Christensen asked each member for her or his view and received a range of suggestions. Many members raised issues that they thought should be considered along with the initial reserve requirement, such as interim assessments of progress, project management experience and accountability, and the technical complexity of the science package and mission objectives. Greater vigilance by NASA in providing fiscal management was suggested,

particularly in relation to identifying problems early enough for descoping to be a useful cost management option. Members discussed the pros and cons of different ways to inform the science review panel of results from the TMCO review, during the initial competition for phase A. Another topic was how best to disseminate project management experience and lessons learned to the science community (prospective PIs), the current set of PIs, and project contractors.

Before adjourning the day's session, the chair asked members for other topics they wished the committee to discuss during this meeting. With respect to the HST servicing options and end-of-mission options, the members agreed that the SScAC should return to these topics after release of the full report from the CAIB and the report of the Bahcall Panel on options for de-orbiting the HST. The strong support in the community for the fourth HST servicing mission was noted. Members thought that the Project Prometheus/JIMO presentations gave an overly narrow view of planetary science and opportunities for JIMO science. In response to a question on the status of the OSS Strategy, Dr. Allen explained that the Office of Management and Budget was requiring NASA to redo the Agency strategic plan, after which the OSS Strategy will be revised for consistency with it.

Tuesday, August 12, 2003

Astronomy and Physics Division Report

Dr. Anne Kinney, Astronomy and Physics Division Director, briefed the SScAC on the division's status. Major budget and program issues are the delays in launching SIRTF, the fifth replan and consequent cost growth of GP-B development, and the delays in servicing the HST. SIRTF is ready for launch on August 23, 2003. The launcher delamination issues have been resolved. Two GP-B review panels, one on science and one on technical issues, were chartered after the January 2003 replan was not approved. Dr. Kinney summarized the charges to and findings of both panels, as well as the subsequent decision by the OSS Enterprise Program Management Council (EPMC) to continue GP-B with strict conditions. The project has met all the requirements since then, including a successful thermal vacuum test, and the GP-B spacecraft is now at the Vandenberg Air Force Base launch site. Launch is scheduled for November 2003.

Three reviews on the HST have been prepared this year or are in progress. A short report to Congress addressed HST science after the next servicing mission. A study on propulsion modules to de-orbit the HST at the end of its operational life has become more essential since the loss of *Columbia* and the uncertainty about a Shuttle mission to bring down the HST. A blue ribbon panel chaired by Dr. John Bahcall is reviewing the NASA plan for the transition from HST to JWST. The panel's final report is expected shortly. Lack of a defined launch date for a fourth servicing mission introduces uncertainty into the status of HST operations beyond late 2005.

Progress this year on JWST includes selection of three instruments and an approach for the Mid-Infrared Instrument (MIRI) that includes collaborating with ESA and the European national space agencies. ESA will manage and guarantee the MIRI contributions of the national agencies. JWST has received approval from the OSS EPMC to enter phase B. The challenge on the JWST replan early this year was to bring the project within the $1.6 billion budget for phases B, C, and D. MIRI was kept, and other JWST instruments were simplified. The aperture size is 6 meters. A JWST contractor has been selected. JWST status will go from *yellow* to *green* in August.

The new Beyond Einstein initiative puts the Laser Interferometer Space Antenna (LISA) and Constellation-X missions into the five-year NASA budget. Multi-agency discussions on dark energy have included DOE and NSF. OSS is working with DOE on a mission like the Supernovae/Acceleration Probe (SNAP). The Office of Science and Technology Policy is

interested in interagency collaboration. Dr. Kinney described her concerns with the potential for the National Astronomy and Astrophysics Advisory Committee (NAAAC) to impact A&P Division budgets and programs. The NAAAC, which has a high profile with OMB and the Congress, has many NASA-related issues on its agenda.

Dr. Kinney reviewed the achievements by A&P programs this year that have been publicized by NASA Space Science Updates. First light observations are coming from the Galaxy Evolution Explorer (GALEX). She described progress on the Stratospheric Observatory for Infrared Astronomy (SOFIA) and new objects observed with the Keck Interferometer. Dr. Kinney then reviewed the status of A&P operating missions.

With respect to developmental missions, a power control unit on Swift was damaged during testing and the schedule consequences are being assessed. The Astro-E2 project is recovering from leaks in the cooling dewar. The Gamma-ray Large Area Space Telescope (GLAST) mission is recovering from withdrawals by two European partners. Herschel has a Kevlar suspension problem that has delayed delivery of flight diodes; the status of project reserves is under review. For the early stage of work on the Terrestrial Planet Finder (TPF) mission, the aim is to have a larger science effort, which will feed into the TPF design.

During the question period, Dr. Kinney discussed the relative value of a SNAP-like mission as a dark energy probe and the use of the ACS on the HST to detect supernovae. Dr. Garth Illingworth, who is a member of the NAAAC as well as the SScAC, described the approach that the NAAAC is taking to avoid interference with the other committees advising the A&P Division. The addition of NAAAC members nominated by OSTP will increase the attention to DOE interfaces with NASA and NSF. She also discussed questions regarding the NASA response to any further problems or delays on GP-B.

Chair's Remarks and GPRA Process

Dr. Christensen led the SScAC in reviewing and revising the input from the staff and the subcommittees with respect to the science goals for FY 2003. Dr. Allen reviewed the process for performance assessment under the Government Performance and Results Act (GPRA) and the SScAC role in assessing the performance on the science goals for inclusion in the annual performance report. Performance reports are drafted by staff, reviewed and revised by the theme subcommittees of the SScAC, then reviewed, revised, and approved by the full SScAC. Dr. Allen introduced Ms. Jennifer Kern, who is now the staff lead for preparing the annual performance plan. He explained the reasons for edit changes in the drafts after the subcommittee reviews and the definitions of the four-level color codes for performance. Blue indicates science accomplishments that were surprising or otherwise exceeded expectations. Green indicates that accomplishments reasonably achieved expectations. Yellow indicates that accomplishments fell short of expectations, but significant progress was made in some areas. Red indicates major shortfalls in scientific progress compared with previous years or reasonable expectations.

Dr. Christensen reviewed what the SScAC had said last year with respect to the GPRA performance rating and use of the color coding. The members discussed ways to calibrate the assessment. Each subcommittee chair then gave the subcommittee's report to the SScAC chair and led a discussion of the subcommittee's GPRA performance assessment for research focus areas (RFAs) within the subcommittee's purview.

SEUS Report with GPRA Discussion

Dr. Edward "Rocky" Kolb, chair of the Structure and Evolution of the Universe Subcommittee (SEUS), discussed the SEUS letter to Dr. Christensen as chair of the SScAC (Appendix F). The

report noted the major resource challenges that the A&P Division was facing and the effect on future SEU programs of the cost overrun for GP-B. The report included comments on the reports to the SEUS from the Astronomy and Physics Working Group and the Science Archive Working Group. The report includes SEUS concerns about the NAAAC, including the potential drain on OSS resources from one interpretation of a NAAAC statement on relaxing the traditional separation between ground-based and space-based astronomy projects. The report also commented on the termination of the Spectroscopy and Photometry of IGM Diffuse Radiation (SPIDR) mission, the mission classes and launch opportunity mix in the Explorer program, and the progress made in technology development by the Office of Aerospace Technology (Code R) in supporting OSS missions.

Dr. Kolb then led the discussion of GPRA assessments by the SEUS. The SScAC agreed on the importance of the exceptional results of the Wilkinson Microwave Anisotropy Probe (WMAP) as the basis for giving RFA 2 a blue rating. For RFA 3, a suite of missions led to results beyond expectations and justified a *blue* rating. After discussion, the SScAC approved the performance ratings (color codes) suggested by the SEUS.

SEC GPRA Discussion

The Sun-Earth Connection Advisory Subcommittee (SECAS) had not met prior to the SScAC meeting, so there was no letter to the SScAC chair to discuss. Dr. Fisher described the basis for his suggested performance ratings for the SEC objectives. The SScAC members agreed that the Ramaty High Energy Solar Spectroscopic Imager (RHESSI) mission had produced unexpected important results during the year. They discussed which RFA was most relevant to these results and should therefore be assigned a *blue* rating. There was also considerable discussion of how to assign results whose scientific importance had developed over several fiscal years. After an initial round of review and revisions, the SScAC agreed to look at the resulting SEC rankings and rationales for its RFAs again on Wednesday morning.

OS Report with GPRA Discussion

Dr. David Spergel, chair of the Origins Subcommittee (OS), presented the OS letter to the SScAC chair (Appendix E). The letter noted the good news about the JWST replan and progress on the SIM. The OS agreed with the A&P Working Group in its concern about the lack of growth in R&A funding, particularly with the cut in the theory program. Like the SEUS, the OS commented favorably on the progress made in Code R technology development in support of OSS technology needs. The OS expressed concern about the possibility of delay or even cancellation of the fourth servicing mission to the HST and noted that the new instruments to be flown to the HST on that mission are ready. Another concern was the apparent lack of competition for the science centers for major NASA missions, and the OS recommended that the science center for TPF be competed openly. (Dr. Charles Beichman recused himself from discussion of the science center issue.) At Dr. Christensen's request, Dr. Spergel agreed to provide draft language for a SScAC recommendation on the science center topic for discussion Wednesday morning. Dr. Spergel discussed the option of an Origins-focused mission as an alternative to adding a program mission class intermediate between the Discovery or MIDEX mission classes and the NASA flagship missions. This Origins mission would be analogous to the Einstein Probes in the Beyond Einstein program. OS is still considering what the specific mission would be.

Dr. Spergel then led the review and discussion of the OS performance ratings for the RFAs in its purview. The SScAC discussed the rating to assign to RFA 6, given that the delay of the SIRTF launch had a major negative impact on expected results in that area. Some results items were moved to other RFA rationales, and the members agreed to add descriptions to some areas to support the rating assigned. The SIRTF delay was moved to RFA 8, and the rating was changed

to *yellow* because of the lack of SIRTF results as anticipated. RFA 10 was rated *blue* because of the unexpected and remarkable detection of an atmosphere surrounding an extrasolar planet. Other supporting results were added to support the *blue* rating.

SSES Report (including Mars Exploration Program) with GPRA Discussion

Dr. Jonathan Lunine, chair of the SSES, presented the subcommittee's letter to the SScAC chair (Appendix G). He asked for the SScAC's support for the SSES comments and recommendations on Project Prometheus and JIMO, as expressed in the letter. The SScAC discussed whether the JIMO mission as proposed represents the best sequence for a Europa mission in accordance with the latest *Decadal Survey*. Dr. Lunine said that the SSES was concerned about insufficient coupling between the science preparation for JIMO (instrument design and selection) and the technology development for nuclear electric power and propulsion. There is an abundance of Galilean satellite science for JIMO, he said, but it isn't represented in Project Prometheus yet. [**Action Items**] The SScAC agreed on the value of being briefed by the JIMO SDT and the Project Prometheus Science Concept Definition Team (SCDT). The SScAC agreed that the vision for Project Prometheus considered by the SCDT should be broader than just solar system exploration. The SSES had received a briefing on the Near-Earth Object survey mandated by Congress and had discussed the size of telescope needed. The SSES letter also included a recommendation on landers for the Jovian moons, with the MSL serving as a prototype. There were comments and suggestions on the four pathways in the next decade plan for Mars exploration. The letter also included the SSES suggestions for recommendations on MESSENGER and the Discovery program, as discussed by the SScAC on Monday afternoon.

Dr. Lunine led the review and discussion of the SSES performance ratings for the RFAs in its purview. He noted that a number of the research results items cited in SSES RFAs were from ground-based observations, but all were NASA funded (R&A work). The SScAC agreed that the sources of research results should be made explicit in each item. After discussion, the SScAC agreed to keep RFA 17 green and show RFA 24 as blue. After discussion of the intended meaning of RFA 18, the SScAC changed its performance rating from yellow to green.

GPRA Wrap-up

Dr. Christensen reviewed the RFA performance ratings on which the SScAC agreed, the changes to be made in supporting details, and the item descriptions to be added or revised by members for discussion on Wednesday or for distribution to the SScAC members by email after the meeting.

Dr. Robert Pfaff gave an informal presentation during the lunch break on the suborbital rocket program, emphasizing the science results that had come from the program in the past and the value of the science that could be done with the planned improvements to rocket capabilities.

Technology Management Update

Mr. Dennis Andrucyk, Program Director of the Mission and Science Measurement (MSM) theme in Code R, described the past year of work with the other NASA enterprises to make the MSM programs more useful in meeting their technology needs. He described the three programs in MSM, which is one of four themes in Code R. MSM technology development generally works at TRLs 1 through 3. As a technology moves past TRL 3, it needs to be picked up in an application within one of the customer enterprises. A Technology Executive Board, with representation from the customer enterprises, has been established to drive what MSM does. This board establishes a joint list of enterprise technology needs and priorities, provides advocacy for technology development efforts, and ensures technology infusion. The board also establishes specific integration/coordination interfaces between MSM and other NASA offices, including the themes within OSS. External interfaces for MSM include the Space Technology Interface and the Space

Test Program. The Space Experiments Review Board is a "ride-share" organization, to give new technologies the opportunity for space testing.

An NRC committee recently reviewed MSM; its overall assessment was that the vast majority of the program consists of good, solid work important to NASA and the nation. The committee judged that 90 percent of the program was in this category. Of 372 tasks, the NRC recommended discontinuing just 15. In response to a question, Mr. Andrucyk described a pool for cofunding (with an application user) technology development from TRL 4 to 6 as a means of providing an incentive for further maturation of new technologies. Dr. Allen asked about integrating technical analyses in the Space Architect effort with the MSM Technology Executive Board. Mr. Andrucyk said he was working on bringing the technical analysis effort into Code R, where it will report to the Technology Executive Board.

Mr. Andrucyk discussed the OSS-wide technology prioritization developed by Dr. Harley Thronson in OSS. OSS has a Technology Blueprint and Technology Implementation Strategy. MSM has released a cross-enterprise NRA, which is based on the technology priorities of the user enterprises, including technology needs identified by the OSS theme road maps. SScAC members asked about the percentage of Code R technology development that is openly competed, including competition from outside the NASA centers. Members were also interested in the distribution of funding among the MSM programs and suggested that there could be less in Computing, Information and Communications Technology (CICT), more in Enabling Concepts and Technologies. Within the Enabling Concepts and Technology Program, advanced measurement and detection is primarily technology for scientific instruments. The Engineering for Complex Systems program comprises three projects: system reasoning for risk management, resilient systems and operations, and knowledge engineering for safe systems.

During the question period, Dr. Christensen and other SScAC members commented favorably on the progress in MSM during the past year. Additional questions were asked about the percentage of Code R and MSM funds that are distributed through openly competed NRAs versus other funding mechanisms. Dr. Kolb urged a meshing of MSM efforts with the user enterprise technology needs in the CICT program, as was done this year for Enabling Concepts and Technologies. Dr. Heidi Hammel raised the need for technology to handle the high rate of data coming from current and future missions to the computer systems that receive, process, and archive the data.

Discussion and Drafting Assignments

The SScAC began this session by discussing recommendations and comments on Project Prometheus and JIMO. During this part of the discussion, Dr. Christensen recused himself and was not present in the meeting. Dr. McComas served as chair for the discussion. Draft language was suggested, and Dr. Hammel and Dr. John Mustard agreed to do further revision and synthesis on statements and recommendations, to be reviewed by the full committee on Wednesday morning.

When Dr. Christensen returned, Dr. McComas asked that the cost cap issue for the Explorer Program be discussed during the Wednesday session. The members also discussed ways to sustain and continue the meshing of OSS technology needs and priorities with technology development in Code R, including the CICT program in particular. A major concern was that the CICT activities should be focused on work that benefits the customer enterprises and can best be done by NASA. The SScAC accepted Dr. Kolb's suggestion to raise some of their concerns about the CICT program with Dr. Weiler on Wednesday. The day's session ended at 5:30 p.m.

Wednesday, August 13, 2003

The chair called the meeting to order at 8:30 a.m. and reviewed the topics to be discussed during the morning session.

Explorer Program Cost Caps

The committee members reviewed the briefing materials that had been prepared by Dr. Paul Hertz, the Explorer Program Scientist, plus notes from Dr. Hertz's presentation of the same briefing slides to a joint session of the SEUS and OS on July 1, 2003. (Dr. Hertz was unable to attend the SScAC meeting on Wednesday.) The chair then led a brief discussion of cost caps for the Explorer Program. Dr. Spergel summarized the response of the OS to Dr. Hertz's presentation at the joint OS–SEUS session. He discussed the reasons for a mission class between the flagship missions and the Explorer MIDEX class. The majority of members of both the OS and the SEUS had voted in favor of the status quo on the Explorer class mix and frequency. Dr. Spergel said that the issue of a larger Explorer class than MIDEX had arisen in part from a concern that only Delta IV rockets would be available as ELVs for Explorer missions. Now that continued procurement of Delta II vehicles has been arranged, the OS view is that it would be better to develop the mission concept for Origins Probes, rather than decrease the access to space provided through the current combination of SMEX and MIDEX AOs.

Dr. McComas described the email discussion about the Explorer mission mix that had occurred among SECAS members, with others from the SEC science community also participating. He reported that there was no support for decreasing the number of SMEX opportunities in the SEC community, which wants more opportunities for smaller missions, not fewer. The SScAC members discussed issues related to ensuring the supply of smaller ELVs, in the Pegasus payload class. Dr. McComas suggested that the national launch policy, which restricts use of foreign launch vehicles, should be revisited if U.S. suppliers of small launchers leave the market. The SScAC agreed to recommend continuation of the current Explorer policy, but in the context of repeating an earlier SScAC recommendation on increasing opportunities for access to space.

Discussion and Letter Section Review

Dr. Allen distributed an updated version of the GPRA performance assessment package. The committee reviewed the revisions and made suggestions for changes and corrections. [**Action Item**] Dr. Allen will make the revisions and final edits, then distribute the draft electronically to the members for final review. Dr. Christensen then led the SScAC in discussing and deciding upon the performance rating (color code) to assign at the level of science objectives (groups of RFAs), based on the RFA ratings.

Dr. Christensen recused himself for the final discussion of draft text on Project Prometheus and JIMO, to be included in a side letter from the SScAC to Dr. Weiler over Dr. McComas's signature. After his return, the committee discussed the draft comment and recommendations on open competition for new or expanded science centers. Dr. Weiler joined the committee during the discussion and provided his views in favor of increasing competition. He described OSS efforts to increase competition for instruments and missions. Anne Kinney added that the SScAC's comments on this topic were relevant to upcoming efforts in the Beyond Einstein program. [**Action Item**] Dr. Weiler suggested, and the committee agreed, that a presentation on science center competition should be on the agenda for a future SScAC meeting.

Briefing to the Associate Administrator and Discussion

Dr. Christensen began the briefing to Dr. Weiler with the SScAC's views on MESSENGER. The situation on this mission represents an outcome that the committee does not want for Discovery

program missions, and the SScAC discussed at length how to avoid similar situations in the future. Procedural changes were discussed for the Discovery AO's and the step 2 down-select. In the case of MESSENGER, there were early signs of later problems, even if the consequences for the budget were not apparent until later. It appears that reserves were inadequate as proposed.

Dr. Weiler agreed that NASA should take a share of responsibility for the failure. The Discovery program, at the community's urging, was set up for failure because PIs were required to manage large programs, with minimal NASA oversight. NASA has signed a new contract with JPL to build up the NASA management office there. The Explorer program office at GSFC will also be expanded. These management oversight changes are already in progress.

Dr. Christensen said that the sense of the SScAC was that more stringent fiscal oversight by NASA is needed earlier in the development process. The SScAC agrees with the new requirement for a minimum of 25 percent reserves in the proposal. It is aware of the tension between offering the most challenging science goals and managing program risk. The SScAC is also aware that supporting MESSENGER will delay future Discovery opportunities. The SScAC will recommend that a distillation of the TMCO review be made available to the science reviewers.

The SScAC members discussed with Dr. Weiler the various factors that contribute to success or failure of PI-led projects, as well as the history of PI-led missions. There was broad agreement between the members and Dr. Weiler on general approaches to managing PI-led, cost-capped programs and communicating lessons learned from recent problems to the science and contractor communities. Workshops for prospective PIs were discussed, to be held at both the preproposal stage and more intensively for projects selected for phase A studies. Dr. Weiler stressed the important role of the SScAC in communicating issues and consequences back to the science community.

Dr. Christensen summarized the results of the GPRA performance assessment by the SScAC. He and Dr. Weiler discussed the importance of the Bahcall panel report for an HST servicing mission. Dr. Weiler said there are no funds budgeted for a servicing mission, if it is delayed beyond FY 2004, nor are there funds budgeted to keep the HST infrastructure going beyond November 2004. The only source for these funds would be other programs in the theme. SScAC members discussed with him alternative approaches to managing a delay in HST servicing.

Dr. McComas led the discussion of JIMO and Project Prometheus. He said that the SScAC is requesting a presentation by the JIMO SDT and the Project Prometheus SCDT. The SScAC also wants to ensure that the SCDT includes representation from all the theme communities. Dr. McComas noted the importance of defining R&A opportunities within Project Prometheus. Drs. Weiler and Hartman replied that there is $10 million for R&A activities included in the Project Prometheus plan. There will be a separate R&A budget for instruments in the budgets for outer planet missions. Dr. Weiler expressed his views on the different rationales for JIMO, depending on whether one's point of view reflects an interest in the technology or the science. From the OSS view, he said, it is important that Project Prometheus have a strong science functionality.

Dr. Christensen summarized the SScAC and subcommittee responses on changing the Explorer program cost caps or mission mix. The SScAC position is that the small end of space investigations ought to be enhanced, not diminished. Potential problems with the current supply of small-payload launch vehicles mean that other solutions for launch should be investigated but should not suggest a move away from smaller missions. The OS and SEUS subcommittees favored the current mix of Explorer classes. The science opportunities offered by SMEX are valuable. There is a place for larger missions but probably not within the Explorer Program. Dr.

Weiler responded by noting the possibilities for major technology pushes in the Suborbital Rocket Program and the balloon program. He added that the New Millennium program has not worked as intended in getting new technology launched as a secondary payload. No commercial market has been developed to provide these ride opportunities. He said it was necessary to fly the New Millennium technology, not just have it sitting on the shelf. [**Action Item**] Dr. Weiler suggested that the SScAC be briefed at its next meeting on revised approaches to the New Millennium program. The SScAC and Dr. Weiler discussed the size of the information technology budget in the MSM program relative to other MSM programs. They discussed the value of the SScAC stating in its letter that OSS should work on developing its computing and information technology needs for the Office of Aerospace Technology (Code R), similar to what was done in the past year for instrument technologies. They also discussed prospects for increasing open competition in Code R and the appropriate focus for the CICT program.

The August 2003 meeting of the SScAC was adjourned at 11:45 a.m.

AGENDA

SPACE SCIENCE ADVISORY COMMITTEE
NASA Headquarters, MIC-6
Washington, D.C.
August 11–13, 2003

Monday, August 11

8:30	Chair's remarks and Agenda Review	A. Christensen
9:00	OSS Status and Q&A	E. Weiler
10:00	**BREAK**	
10:10	SEC Division Report	R. Fisher
10:30	SSED Division Report	C. Hartman
10:50	Project Prometheus/Nuclear Systems	A. Newhouse
11:10	Mars Exploration Program Report	O. Figueroa
11:30	Astronomy and Physics Division Report	A. Kinney
Noon	**LUNCH:** Initial Results from the Great Observatories Origins Deep Survey	M. Giavalisco
1:00	Community Mission Line Cost Issues Introduction	E. Weiler
1:10	Explorer Cost Caps	P. Hertz
1:45	MESSENGER Science and Project Status	S. Solomon
2:30	MESSENGER and Discovery Programmatics	C. Hartman
3:00	**BREAK**	
3:15	Committee Discussion	A. Christensen
4:00	Project Prometheus/JIMO Mission	R. Taylor
4:30	Project Prometheus/JIMO Science	C. Hartman

7:00 **Committee Dinner (District Chophouse & Brewery)**

Tuesday, August 12

8:30	Chair's Remarks and GPRA Process	A. Christensen/M. Allen
8:45	SECAS report with GPRA Discussion	D. McComas/A. Christensen
9:45	**BREAK**	
10:00	SEUS Report with GPRA Discussion	R. Kolb/A. Christensen
11:00	OS report with GPRA with discussion	D. Spergel/A. Christensen
Noon	**LUNCH:** Sounding Rocket Science	R. Pfaff
1:00	SSES (including Mars) Report with GPRA Discussion	J. Lunine/A. Christensen
2:00	GPRA wrap-up	A. Christensen
2:30	Technology Management Update	H. Thronson/D. Andrucyk
3:30	**BREAK**	
3:45	Discussion and Assignments	A. Christensen

Wednesday, August 13

8:30	Discussion and Letter Finalization	A. Christensen
10:30	Briefing to AA and Discussion	A. Christensen/E. Weiler
11:30	**ADJOURN**	

Dr. Andrew B. Christensen, Chair
The Aerospace Corporation

D. David L. Akin
Associate Professor of Aerospace Engineering, Space Systems Laboratory
University of Maryland

Dr. Charles A. Beichman
Chief Scientist, Origins Program
Jet Propulsion Laboratory, NASA

Dr. David W. Deamer
Department of Chemistry and Biochemistry
University of California, Santa Cruz

Dr. Heidi B. Hammel
Space Science Institute

Dr. Fiona A. Harrison
Division of Physics, Mathematics, and Astronomy
California Institute of Technology

Dr. Roderick A. Heelis
William B. Hanson Center for Space Sciences
University of Texas at Dallas

Dr. Garth D. Illingworth
Professor of Astronomy
Department of Astronomy and Astrophysics
University of California, Santa Cruz

Dr. Judith T. Karpen
Naval Research Laboratory

Dr. Andrew C. Klein
Nuclear Engineering and Radiation Health Physics
Oregon State University

Dr. Paul H. Knappenberger
President, Adler Planetarium and Astronomy Museum

Dr. Edward W. Kolb
Theoretical Astrophysics
Fermi National Accelerator Laboratory

Mr. Martin P. Kress
Vice President/General Manager, NASA Sector
Battelle Memorial Institute

Dr. Jonathan I. Lunine
Professor of Planetary Science and Physics
University of Arizona

Dr. David J. McComas
Executive Director
Southwest Research Institute

Dr. Jeremy R. Mould
Director
National Optical Astronomy Observatory

Dr. John F. Mustard
Department of Geological Sciences
Brown University

Dr. David N. Spergel
Department of Astrophysical Sciences
Princeton University

Dr. Marc S. Allen (Executive Secretary)
Office of Space Science
NASA Headquarters
300 E. Street, S.W.
Washington, D.C. 20546-0001
Tel: 202-358-2470
FAX: 202-358-3092
Email: marc.allen@nasa.gov

Ms. Marian R. Norris (Administrative Officer)
Office of Space Science
NASA Headquarters
300 E. Street, S.W.
Washington, D.C. 20546-0001
Tel: 202-358-4452
FAX: 202-358-3092
Email: mnorris@nasa.gov

SPACE SCIENCE ADVISORY COMMITTEE
August 11–13, 2003
NASA Headquarters
Washington, D.C.

MEETING ATTENDEES

Committee Members:

Christensen, Andrew, *Chair*	The Aerospace Corporation
Allen, Marc, *Executive Secretary*	NASA Headquarters
Beichman, Charles	NASA/JPL
Deamer, David	University of California, Santa Cruz
Hammel, Heidi	Space Science Institute
Harrison, Fiona	California Institute of Technology
Heelis, Roderick	University of Texas at Dallas
Illingworth, Garth	University of California, Santa Cruz
Karpen, Judith	Naval Research Laboratory
Klein, Andrew	Oregon State University
Kolb, Edward "Rocky"	Fermi National Accelerator Laboratory
Kress, Martin	Battelle Memorial Institute
Lunine, Jonathan	University of Arizona
McComas, David	Southwest Research Institute
Mould, Jeremy	National Optical Astronomy Observatory
Mustard, John	Brown University
Spergel, David	Princeton University

NASA Attendees:

Andrucyk, Dennis	NASA Headquarters
Bergstralh, Jay	NASA Headquarters
Brody, Steve	NASA Headquarters
Cannon, Dudley	NASA Headquarters
Cohen, Ellen	NASA Headquarters
Dastoov, Minolo	NASA Headquarters
Fisher, Richard	NASA Headquarters
Gay, Charles	NASA Headquarters
Geldzahler, Barry	NASA Headquarters
Hasan, Hashima	NASA Headquarters
Hayes, Jeffrey	NASA Headquarters
Hertz, Paul	NASA Headquarters
Hirschbein, Murray	NASA Headquarters
Howard, Rick	NASA Headquarters
May, Lisa	NASA Headquarters
Montemerlo, Mel	NASA Headquarters
Moore, Chris	NASA Headquarters
Norris, Marian	NASA Headquarters
Ormes, Jonathan	NASA/GSFC
Peterson, W. K.	NASA Headquarters
Rinsland, Pamela	NASA Headquarters
Rosendhal, Jeffrey	NASA Headquarters

NASA Attendees (continued):

Rummel, John D.	NASA Headquarters
Salamon, Michael	NASA Headquarters
Saunders, Steve	NASA Headquarters
Savage, Don	NASA Headquarters
Smith, Eric	NASA Headquarters
Sorrels, Carrie.	NASA Headquarters
Taylor, Ray	NASA Headquarters
Thronson, Harley	NASA Headquarters
Varsi, Giulio	NASA/JPL
Vondrak, Richard	NASA/GSFC
White, Nicholas	NASA/GSFC
Woods, Dan	NASA Headquarters

Other Attendees:

Anderson, Bob	Boeing
Appleby, John	APL
Beckwith, Steven	AURA/Space Telescope Science Institute
Berger, Brian	Space News
Beres, Kathleen	Orbital
Bordi, Francesco	The Aerospace Corporation
Boxelder, Jacqueline	BE
Boyd, Karen	BE
Bruno, Mary	Ball Aerospace
Eckfield, Stephanie	BE
Giavalisco, Mauro	Space Telescope Science Institute
Goralczyk, Steve	NGST
Herman, Dan	Brashear LP
Kaminski, Amy	Office of Management and Budget
Malay, Jon	Lockheed Martin
Margon, Bruce	Space Telescope Science Institute
McNutt, Ralph	The Johns Hopkins University, Applied Physics Laboratory
Morris, David	Swales Aerospace
Purdy, William	Ball Aerospace
Riley, Annette	BE
Rodrigues, Michelle	SRI
Solomon, Sean	Carnegie Institution
Whitney, Pamela	National Research Council, Space Studies Board
Widder, Joel	California Institute of Technology

SPACE SCIENCE ADVISORY COMMITTEE
August 11–13, 2003
NASA Headquarters
Washington, D.C.

LIST OF PRESENTATION MATERIAL[1]

1) Dr. Edward J. Weiler, Associate Administrator, NASA Space Science. *NASA Space Science: An Update Presented to the Space Science Advisory Committee*.
2) Dr. Richard Fisher, Director, Sun-Earth Connection Division. *Review of the SEC Division*.
3) Dr. Colleen Hartman, Director, Solar System Exploration Division. *Solar System Exploration Overview to the SScAC*.
4) D. Orlando Figueroa, Director, Mars Exploration Program. *The Mars Exploration Program*. Presentation to the Space Science Advisory Committee.
5) Mr. Alan Newhouse, Director, Project Prometheus. *Project Prometheus, The Nuclear Systems Program: Revolutionizing Solar System Exploration.* Presentation to the Space Science Advisory Committee.
6) Dr. Mauro Giavalisco, Space Telescope Science Institute. *The Great Observatories Origins Deep Survey: Preliminary Results from the ACS*.
7) Dr. Sean C. Solomon, Carnegie Institution of Washington. *The MESSENGER Mission to Mercury*. Presentation to the Space Science Advisory Committee.
8) Dr. Colleen Hartman, Director, Solar System Exploration Division. Briefing slides on MESSENGER and Discovery Program programmatics.
9) Dr. Jonathan I. Lunine, Chair, Solar System Exploration Subcommittee. *SSES Analysis of MESSENGER Issues.*
10) Dr. Colleen Hartman, Director, Solar System Exploration Division. *Jupiter Icy Moons Orbiter: Mission Science*.
11) Ray Taylor, NASA Office of Space Science. *Project Prometheus: Jupiter Icy Moons Orbiter*. Presentation to the Space Science Advisory Committee.
12) Dr. Anne L. Kinney, Director, Astronomy and Physics Division, NASA Office of Space Science. *Status of Astronomy and Physics Division*. Presentation to the Space Science Advisory Committee.
13) Letter to Andrew Christensen, Chair, Space Science Advisory Committee, from Jonathan I. Lunine, Chair, Solar System Exploration Subcommittee. Subject: Solar System Exploration Subcommittee Meeting.
14) Letter to Andrew Christensen, Chair, Space Science Advisory Committee, from David Spergel, Chair, Origins Subcommittee. August 10, 2003.
15) Letter to Dr. G. Wayne Van Critters, Division Director, Division of Astronomical Sciences, National Science Foundation, and Dr. Anne Kinney, Director, Astronomy and Physics Division, NASA, from the National Astronomy and Astrophysics Advisory Committee. April 23, 2003.
16) Dr. Marc S. Allen, Executive Secretary, Space Science Advisory Committee. *FY03 Science Progress Assessments*. Integrated GPRA input. Edited and unedited versions.

[1] Presentation and other materials distributed at the meeting are on file at NASA Headquarters, Code SB, Washington, DC 20546.

17) Dr. Paul Hertz, Explorer Program Scientist. *Explorer Options for the Future*. Presentation to the Space Science Advisory Committee.

18) Dr. Robert Pfaff, Project Scientist, Sounding Rockets, NASA Goddard Space Flight Center. *Rocket Program Science*. Presentation to the Space Science Advisory Committee.

19) Harley A. Thronson, Technology Director, NASA Office of Space Science, and Dr. Dennis J. Andrucyk, Program Director, Mission and Science Measurement, NASA Office of Aerospace Technology. *Technology Management: Mission and Science Measurement (MSM) Technology*. Presentation to the Space Science Advisory Committee.

SPACE SCIENCE ADVISORY COMMITTEE

September 6, 2003

Dr. Edward Weiler
Associate Administrator for Space Science
NASA Headquarters
Washington, DC 20546

Dear Dr. Weiler,

The Space Science Advisory Committee (SScAC) met in public session August 11-13, 2003 at NASA headquarters. We welcomed Dr. David Deamer as a new member of the committee and Drs. Fiona Harrison and Andrew Klein as pending members. We had excellent attendance from the membership of the committee throughout the meeting. My thanks also to Marc Allen, Marian Norris and their staff for their leadership and efforts in support of a successful meeting.

The meeting was dominated by consideration of two important issues: the financial health of the Discovery program and in particular the MESSENGER mission. It was of great interest to the committee and, based on the number in the gallery, to external observers as well. An evaluation of progress in Space Science in terms of the GPRA (Government Performance and Results Act) dominated the second day of our meeting, but despite the mandatory aspects of the review, it was satisfying to contemplate the outstanding science progress we are witnessing in the Office of Space Science missions.

In addition we were pleased to hear from members of your staff and others within the NASA organization. We were grateful for their flexibility with regards to the agenda since there were more rearrangements than normal. The committee was impressed with the informative, concise and insightful briefings that were brought before us by Colleen Hartman, Anne Kinney, Richard Fisher, Al Newhouse, Orlando Figueroa, Ray Taylor, Jay Bergstralh, and Dennis Andrucyk. We apologize for our inability to accommodate Dr. Paul Hertz's oral presentation but found copies of his charts very useful.

We were delighted to hear outstanding science presentations during our noon hour each day. Dr Mauro Giavalisco, Space Telescope Science Institute, addressed the topic of the origins deep survey and the search for high-redshift supernovae. He described research to address fundamental question regarding the origins of galaxies, black holes and the dynamics of the cosmic expansion. Dr Robert Pfaff, NASA/GSFC, reviewed the science results and future possibilities involving the NASA sounding rocket program. Despite the acknowledged value of the program, there are issues regarding the health and capabilities of the rocket program and the full sub-orbital program that will continue to draw the attention of SScAC.

Following our meeting we learned that Dr. Colleen Hartman, Director of the Solar System Exploration Division, announced her plan to vacate her post at NASA effective September 22. The SScAC wishes to express its heart-felt appreciation for her service to our community. She has skillfully led the division through a very exciting time of scientific exploration and has

formulated programs and missions that will impact the science for years to come. We will, of course, miss her but at the same time wish her all the best in her new adventure.

I recused myself during the presentations and discussion of the Prometheus Project, therefore a separate letter summarizing the committee discussion will be submitted to you by David McComas, chair of SECAS, who led the committee in my absence. The record should also show that Dr. Charles Beichman recused himself during the discussion on science centers. Specific comments on other items and recommendations follow.

Messenger

The SSAC endorses the SSES recommendation NOT to cancel the Mercury Messenger mission despite its recent cost growth above its cost cap**. We urge NASA to be especially vigilant through the completion of Messenger's Thermal Vacuum test in particular to ensure that the remainder of the development of Messenger proceeds smoothly to a launch no later than August 2004.** If such progress cannot be assured, then SScAC recommends that NASA consider terminating the Messenger program**.**

We adopt this recommendation on the basis of the strong scientific case for the project articulated by SSES. Also the briefings by the PI, Dr Sean Solomon, and Dr. Colleen Hartman suggested that Messenger has an excellent likelihood of making a May 2004, or at latest an August 2004, launch date. The committee recognizes that the additional costs incurred by MESSENGER will delay the release of the Announcement of Opportunity for the next Discovery mission.

The level of reserves initially proposed by Messenger and accepted by NASA appears in hindsight to have been unreasonably low for an extremely challenging mission. **SScAC endorses the new policy of requiring at least a 25 percent reserve for Discovery missions, based on the need to balance scientific return and program risk.**

There were a number of early warning signs that Messenger was in trouble, including significant underspending early in the program (indicative of slow technical progress), difficulty in staffing up, and departure of key project personnel. Early identification of these problems could have resulted in timely intervention or invoking descope options that might have saved significant resources

In terms of the overall Discovery selection and development process, the committee has the following recommendations intended to enhance the likelihood of successful outcomes for Discovery (and other missions). The committee notes that other NASA missions may also benefit from consideration of these ideas.

- SScAC recommends that NASA develop a formal process for collecting the lessons learned from problems in both PI-led and in-house NASA missions, and for incorporating this knowledge into the acquisition/development process to help avoid recurrence of these problems on future missions. **Each step in the creation of a new mission including the AO process, the evaluation process, the selection process, the funding process, and so forth should be**

examined for process improvement. The SScAC would like to have further briefings from PIs and NASA officials to expand its understanding of project management and development.

- **SScAC recommends that NASA incorporate to a greater extent the TMCO results into the science review process.** Having such knowledge could help the evaluating scientists weigh the risks of a given project against its promise. The SScAC felt that this was a very important issue. Having extensive experience in the proposal review process, the committee felt that better insight into the technical and costs risks would be valuable for arriving at more balanced science ratings for proposed investigations. We also realize that there is no simple approach for all situations, but regard the issue deserving of serious consideration.

- **SScAC recommends that NASA should increase the depth, duration and funding of the Step 2 process, possibly by deferring the final down selection of the missions to be selected for flight until the confirmation review.** This approach puts more upfront costs into the Discovery program, but could reduce the cost and schedule risk inherent in selecting projects that have not been studied to an appropriate depth. After a mission has entered Phase C/D, descope options usually are not effective in reducing overall cost, therefore greater emphasis on the early definition stages will give greater flexibility in the exercise of descope options.

- **SScAC recommends that NASA assess all existing Discovery programs for adequacy of reserves.**

Science Centers

The committee is very concerned about the trend toward non-competed science centers for major NASA missions (e.g., SIM, LBTI, and JWST). Competition will produce strong centers at lower cost to NASA.

The OS was informed that an open competition would have a severe programmatic impact on SIM but some subcommittee members were not convinced of this. Because TPF is still in its architectural definition phase, we encourage an open competition for its science center, as for all upcoming major science centers **The SScAC requests a presentation on OSS policy for competing science centers.**

The Future of HST

SScAC discussed some of the options for the future of the Hubble Space Telescope. However, at the time of the meeting, several key reports had not been released, including the report from the "blue ribbon" committee led by John Bahcall on the HST/JWST transition, and more importantly, the report from the Columbia Accident Investigating Board (CAIB). As pointed out both at the SScAC meeting and in the subsequently-released Bahcall Committee Report, any future plans for HST will depend critically on the Space Shuttle program. **SScAC will need to revisit this topic at its next meeting, by which time the CAIB report should be made public and some understanding of realistic options should be known.**

Explorer Mission SMEX vs. MIDEX Mix

The Explorer program comprising a mix of mid-sized (MIDEX) missions, capped at $180M, and small (SMEX) missions, capped at $120M, plus missions of opportunity is regarded widely as having been highly successful. Because of the value of this program to space science, SScAC became very concerned when it learned of 1) possible future problems of securing appropriate launch services for these missions 2) possible future decline in the compelling science in the SMEX category and 3) the possibility of adjusting the flight rate and raising the cost cap on the MIDEX missions. Therefore we asked the sub-committees to consider whether changes in the mix of missions in the Explorer program were warranted.

The OS and SEUS met in joint session to review the Explorer situation. The SECAS did not have a formal meeting so responses were received via e-mail. The sub-committees stressed the critical importance of frequent access to space for ensuring scientific progress and for training our future scientists. Frequent access to space, the relatively short development cycle and the excellent science were all cited as strengths of the program**. SScAC endorses the recommendation of all committees that the present mix of 2 SMEXs and 2 MIDEXs missions every three years be maintained.**

Thanks again for the opportunity to work with you in service to NASA. We all appreciate the opportunity to engage in conversation with you and discuss issues of importance to space science.

Sincerely

Andrew B. Christensen
SScAC Chair

FY 2003 GPRA Performance results:

The external expert review of NASA's progress in its Space Science research focus areas was performed by the Space Science Advisory Committee. Results are as follows:

Objective	#	Research Focus Area	Theme	RFA *	Objective *
1. Understand the structure of the universe from its earliest beginnings to its ultimate fate	1 2	Identify dark matter and learn how it shapes galaxies and systems of galaxies Determine the size, shape, age, and energy content of the Universe	SEU SEU	GREEN BLUE	B
2. Explore the ultimate limits of gravity and energy in the universe	3 4 5	Discover the sources of gamma-ray bursts and high energy cosmic rays Test the general theory of relativity near black holes and in the early Universe, and search for new physical laws using the universe as a laboratory Reveal the nature of cosmic jets and relativistic flows	SEU SEU SEU	BLUE GREEN GREEN	G
3. Learn how galaxies, stars, and planets form, interact, and evolve	6 7 8 9	Observe the formation of galaxies and determine the role of gravity in this process. Establish how the evolution of a galaxy and the life cycle of stars influence the chemical composition of material available for making stars, planets, and living organisms. Observe the formation of planetary systems and characterize their properties Use the exotic space environments within our Solar System as natural science laboratories and cross the outer boundary of the Solar System to explore the nearby environment of our galaxy	ASO ASO ASO SEC/ASO	BLUE GREEN YELLOW GREEN	G
4. Look for signs of life in other planetary systems	10 11	Discover planetary systems of other stars and their physical characteristics. Search for worlds that could or do harbor life.	ASO ASO	BLUE GREEN	B
5. Understand the formation and evolution of the Solar System and Earth within it	12 13 14	Inventory and characterize the remnants of the original material from which the Solar System formed Learn why the planets in our Solar System are so different from each other. Learn how the Solar System evolves.	ESS ESS ESS	GREEN GREEN GREEN	G
6. Probe the origin and evolution of life on Earth and determine if life exists elsewhere in our Solar System	15 16 17 18	Investigate the origin and early evolution of life on Earth, and explore the limits of life in terrestrial environments that might provide analogues for conditions on other worlds. Determine the general principles governing the organization of matter into living systems and the conditions required for the emergence and maintenance of life. Chart the distribution of life-sustaining environments within our Solar System, and search for evidence of past and present life. Identify plausible signatures of life on other worlds.	ESS ESS ESS ESS	GREEN GREEN GREEN GREEN	G
7. Understand our changing Sun and its effect throughout the Solar System	19 20 21	Understand the origins of long- and short-term solar variability Understand the effects of solar variability on the solar atmosphere and heliosphere Understand the space environment of Earth and other planets	SEC SEC SEC	GREEN GREEN BLUE	G
8. Chart our destiny in the Solar System	22 23 24	Understand forces and processes, including impacts, that affect the habitability of Earth Develop the capability to predict space weather Find extraterrestrial resources and assess the suitability of Solar System locales for future human exploration	ESS/SEC SEC ESS	GREEN GREEN BLUE	G

* Note: please see page fifteen of the the NASA FY 2003 Performance and Accountability Report for explanation of color rating system. The report can be found at http://www.nasa.gov/pdf/56091main_NASA_FY2003_PAR.pdf